Space Technology Research Grants

Understanding and Mitigating Scale Formation on Membranes Used for Membrane Distillation of Wastewater During Space Travel

Completed Technology Project (2016 - 2019)

Project Introduction

Water sustains life, and on space missions this resource is a vital commodity that must be safeguarded. For short-term missions it is most reliable and cost-effective to transport water from Earth, but for long-term missions beyond the earth's orbit, water must be recycled from wastewater sources such as urine, humidity condensate, and hygienic wash water. Maintaining an open-loop water supply system is simply not feasible for such long-distance missions. One challenge to closing this supply loop and increasing the water recovery rates is that as water is extracted from wastewater sources, contaminants become more concentrated in the wastewater, and solids begin to precipitate from the wastewater/brine and foul the treatment systems. One promising technology for treating concentrated space mission wastewater is membrane distillation. Membrane distillation is a thermally-driven technology that uses a hydrophobic membrane to separate pure water vapor from the heated liquid wastewater stream from which the water vaporizes. This technology can be powered by low-grade waste heat and is more resistant to fouling than pressure-driven systems such as reverse osmosis. However, because fouling/scaling is still an issue in membrane distillation, my proposed research project seeks to understand and mitigate this scaling. The specific objectives of this study are to understand the chemistry behind scaling of space mission wastewater, to understand how membrane surface properties affect scaling, and to develop anti-scaling methodologies for membrane distillation systems. To understand the chemistry behind scaling, I will perform experiments using a model space mission wastewater solution and analyze the produced scale and the water constituents to determine which chemicals are responsible for scaling. Also of interest is whether particle aggregation leading to scaling occurs in solution prior to precipitation onto the membrane, or whether this aggregation occurs directly on the membrane. After studying the chemistry of scaling, experiments will be performed using membranes having a variety of surface properties, including different pore sizes, degrees of hydrophobicity, and membrane materials. This will give a complete picture of how wastewater chemistry and membrane surface properties affect the scaling process. The final and most practical objective of this study ”developing anti-scaling methodologies ”will be guided by the previous phases providing understanding of the scaling process. Several potential methods for mitigating scaling include using nanotechnology to modify the membrane surface, selectively removing scaling ions, and modifying the hydrophobicity/hydrophilicity of the membrane surface. Another innovative technique involves the use of a nanotemplate that creates an energetic preference for particles to aggregate on the nanotemplate instead of on the membrane. By improving our understanding of scale formation during membrane distillation of space mission wastewater and by finding ways to mitigate this scaling, this research will make substantial progress toward closing the wastewater treatment/water supply loop. This type of self-sustaining life support technology will enable NASA to penetrate further into space, opening the door for further discoveries. However, my research also has tremendous application for the development of water

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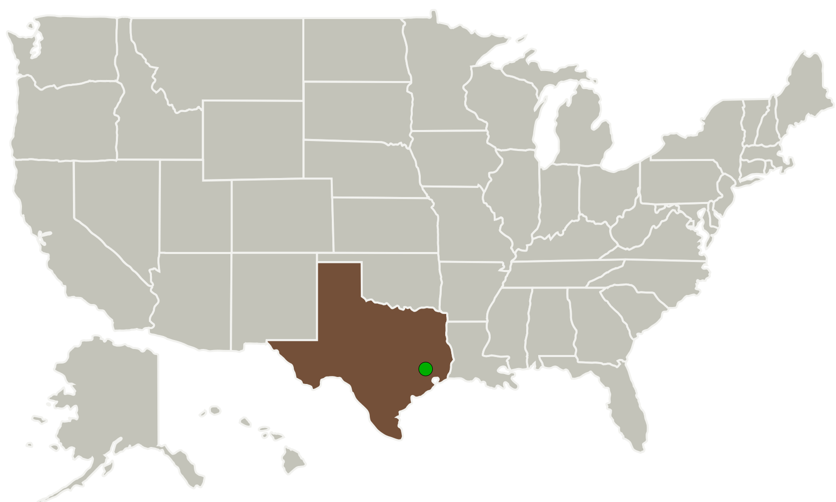
treatment systems on Earth, since scale formation and mitigation are critical issues in all membrane-based treatment systems. Consistent with the goals of the NASA Space Technology Research Fellowship, this proposed project will generate high-impact research benefiting not only NASA Environmental Control and Life Support Systems development, but also broader national research endeavors.

Anticipated Benefits

By improving our understanding of scale formation during membrane distillation of space mission wastewater and by finding ways to mitigate this scaling, this research will make substantial progress toward closing the wastewater treatment/water supply loop. This type of self-sustaining life support technology will enable NASA to penetrate further into space, opening the door for further discoveries. However, my research also has tremendous application for the development of water treatment systems on Earth, since scale formation and mitigation are critical issues in all membrane-based treatment systems.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Rice University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Qilin Li

Co-Investigator:

Seth Pedersen

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Organizations Performing Work	Role	Type	Location
Rice University	Lead Organization	Academia	Houston, Texas
Johnson Space Center(JSC)	Supporting Organization	NASA Center	Houston, Texas

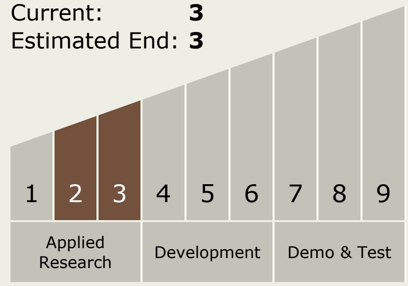
Primary U.S. Work Locations
Texas

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  - └ TX06.1 Environmental Control & Life Support Systems (ECLSS) and Habitation Systems
    - └ TX06.1.2 Water Recovery and Management

Target Destinations

Earth, The Moon, Mars